XVIII. *The secretion of potassium hydroxide by* Dicranura vinula (*imago*), *and the emergence of the imago from the cocoon.*

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THE investigations of which I now publish the results were undertaken at the instigation of Mr. F. Merrifield, to whom I must at once acknowledge my utmost indebtedness, not only for his suggestion, but also for a most generous supply of material wherewith to conduct my experiments and observations. I must also thank my colleague, the Rev. S. D. Titmas, for much kind assistance and advice.

More than forty-five years ago Mr. Merrifield observed that the imago of *D. vinula* produced an alkaline fluid at the time of emergence from the pupa. The observation was, I believe, never published, and no further work, so far as I am aware, has been done on the subject until, at Mr. Merrifield's suggestion, I undertook its continuance. It is well known that the larva of *D. vinula* spins an exceedingly hard cocoon, composed partly of a tough semitransparent substance, which is, as I conceive it, virtually a mass of agglutinated silk, and partly of portions of bark gnawed off from the tree on which the cocoon is constructed. The whole forms a hard unyielding protection to the enclosed pupa. Notwithstanding the character of this wall, the imago pierces it at the proper season without difficulty. The means whereby this is accomplished I hope to show in the following pages.

Two distinct points present themselves for investigation. (1) The means by which the cocoon is softened; (2) the apparatus employed in tearing open the cocoon when softened.

I. *The softening of the cocoon.*

A number of pupæ were cut out from their cocoons, and enclosed in red litmus-paper in such a way as to compel the moths to pierce the paper in order to effect their escape. In each case the papers were moistened by the emerging imago with a fluid which produced a deep blue stain of varying dimensions. The alkalinity of the fluid was thus proved. These stained papers were useless for analysis owing to the impurities present in the litmus-papers. Accordingly some forty pupæ were enveloped in best Swedish filter-paper, which is entirely free from all impurities, and contains no substances soluble in water. There was a slight difficulty in arranging the paper so as to afford sufficient obstruction to the emerging imago. Double thickness of the paper was too much for the imago to penetrate, and a single thickness not sufficient to provoke the maximum discharge of the softening fluid. About ten pupæ were enclosed in glass tubes, with their heads against the closed ends. The majority of the pupæ emerged successfully from the papers, yielding me thirty-two papers, each stained very faintly by the ejected fluid. The pupæ in glass tubes did not succeed so well—only four hatched (one is still alive, and evidently going over to next year), and of these only one was of any use: the fluid in the other three cases being spoiled by mixture with excrementitious matter. The one tube I was able to make use of contained a few drops of clear watery liquid. This tube I obtained in a satisfactory condition by fortunately seeing the imago just struggling to get free. I accordingly waited till I judged that most of the fluid was ejected, and then withdrew the moth and pupa-case from the tube with a pair of fine forceps.

I then proceeded to analyse the stains on the papers. All stains of excrement were carefully cut away, and only absolutely pure stains were retained. These were placed in distilled water, and raised to a temperature of about 90° C.; at the same time the papers were kept in motion by stirring them with a glass rod, so as to reduce them to pulp. I then filtered off the liquid, and condensed it by evaporation at about the same temperature. When cool, analysis yielded the following results:—(1) The fluid was decidedly alkaline; (2) there was present

a mere trace of a chloride—hardly enough to be sure of; (3) potassium hydroxide was present in considerable quantity. The presence of potassium was proved by (*a*) the platinum perchloride test; from the yellow crystalline precipitate so obtained after treatment with alcohol, the platinum was separated by heat, and potassium chloride recovered; (*b*) the sodium and hydrogen tartrate test; (*c*) the characteristic colour imparted to the flame of a Bunsen's burner; (*d*) the remainder of the liquid was evaporated to dryness, and yielded a whitish solid, which was strongly alkaline, and deliquesced on exposure to the air, eventually forming potassium carbonate. Having arrived at these results, I confirmed them as far as possible with the few drops of pure liquid in the glass tube, from which also I obtained the same results, including the presence of a very small quantity of a chloride—again almost too little to be quite sure about.

My next step was to try the relative caustic powers of potassium hydroxide and sodium hydroxide on the cocoons—applying the solutions to the inside. I took solutions of both substances of equal strength, and placed a few drops in four cocoons—two with each solution: the potassium hydroxide reduced the cocoons to which it was applied to a soft pulp in less than three minutes, whereas the sodium hydroxide took more than fifteen minutes to produce the same result. This of course was to be expected, owing to the superior caustic power of potassium hydroxide on most organic substances. It was thus proved that the imago of *D. vinula* produces caustic potash in order to soften its cocoon, and that this substance is better suited to this end than the other of the two commoner caustic substances.

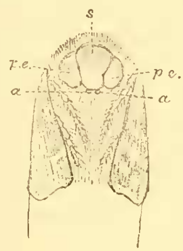
II. *The apparatus employed in perforating the cocoon.*

The imago invariably emerges from the cocoon wearing as a shield a portion of the pupa-case (see fig. 1, p. 291). This "shield" consists of the median dorsal piece (figs. 1—3, s) of the head of the pupa, extending as far as the labrum (p. l.) towards the ventral surface, and also of the two pupal eyes (p. e.), which project laterally further towards the ventral surface than the median labrum.

At first sight it appears that the "shield" is the tool used to thrust against the softened cocoon, but closer

examination reveals a far more efficient apparatus. I placed one individual in absolute alcohol the instant it emerged from the cocoon, and so secured it with the "shield" still on. Examination of this specimen showed two small sharp points (figs. 1 & 2, *a a*) projecting in front of, and just ventral to, the pupal labrum from the labrum of the imago. These points are entirely concealed by the abundant fluffy scales on the head of the fully developed imago. If the head is "plucked," they are readily seen, even with the naked eye (see fig. 1). The points are about 0.5 mm. in length, and about 0·75 mm. apart, and project forwards and downwards: their outer margins are thickened, and the two together are carried upon a slightly thickened elevation of the imago's head. On each side of this elevation is an elongate pit (fig. 2, *b b*), open towards its ventral aspect, and running up dorsally towards the vertex of the head to end about a third of the way up in a socket. The total length from the socket to apex of points is about 1·2 mm. On the inner surface of the pupal "shield," *i.e.*, the side which is in contact with the underlying imago, is a pair of recurved hooks (fig. 4, *h h*), which fit accurately into the groove and socket of each side—the grooves serving as guiding lines towards the sockets. It is thus impossible for the "shield" to be removed by any upward pressure, for all pressure in that direction merely serves to lock the "shield" more firmly to the head of the imago below. On the other hand, downward pressure causes the hooks to come out of the sockets, to slide along the grooves, and the shield may be set free. These appearances warrant the conclusion that the imago attacks the softened inner surface of the cocoon with the above-mentioned pair of pointed processes, and that the "shield" serves to protect the eyes and head of the imago from injury which might otherwise result from friction against the walls of the cocoon. Probably each stroke is made in a downward and forward direction by the head of the animal, and probably fresh applications of the potassium hydroxide are made as each softened layer is in turn removed in order to soften the succeeding layers. I believe the potassium hydroxide is produced from the mouth—at any rate I could discover no other aperture of any kind: if this surmise be correct, it seems probable that the muscular efforts necessary for scraping

at the cocoon may also serve to eject successive quantities of potassium hydroxide.



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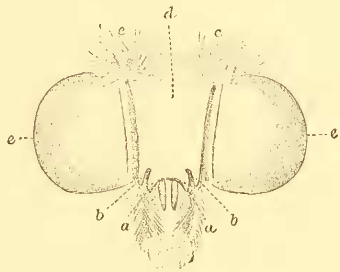

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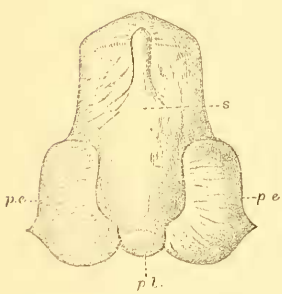

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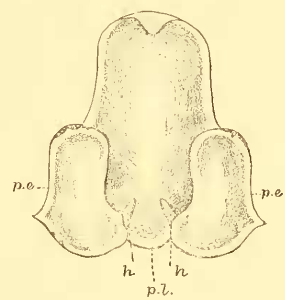

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Fig. 1.—Ventral view of freshly emerged imago of *D. vinula*, showing pupal shield, *s*, pupal eyes, *p. e.*, and processes of labrum of imago, *a a*, just visible below shield.

Fig. 2.—Head of imago denuded of scales, showing, *a a*, the labral processes; *b b*, grooves terminating above in sockets for reception of *h h* in fig. 4; *c c*, basal joint of antennæ; *d*, median anterior region of head; *e e*, eyes.

Fig. 3.—Outer surface of pupal shield, slightly flattened to show its full extent: *p. e.*, pupal eyes; *s.*, points to same spot as in fig. 1. *p. l.*, pupal labrum.

Fig. 4.—Inner surface of same. *h h*, hooks for attachment of shield by locking with *b b*, fig. 2. Other letters as before.

I may mention that the whole surface of the body of a freshly emerged imago is damp with an alkaline fluid, but this is probably due to the whole body having to pass through the aperture in the cocoon which is moist with the hydroxide. I am not able to speak with certainty on the manner in which the imago gets rid of the

"shield." The only one I saw free itself did so at the moment it met a vertical surface when crawling along a horizontal board; it looked as though the animal struck the shield accidentally against the vertical side of the box, and made an upward movement of the head prior to ascending in order to let the wings hang down. But from this single instance I cannot draw a general conclusion. In this case the shield was on till the vertical side was encountered, and then fell off at once. Certainly, if the "shield" were pressed against a surface, and the head drawn upwards, the former would easily be removed by withdrawal of the hooks from their sockets.

Summary.

I.—The imago of *D. vinula* produces a solution of potassium hydroxide, probably from the mouth, in order to soften the cocoon.

II.—The labrum of the imago bears two sharply pointed processes, used for scraping the inner surface of the cocoon in order to break a way through.

III.—The eyes and median portion of the head of the pupa are retained as a protecting shield over the same structures of the imago until emergence is completed.